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PANEL DATA, COINTEGRATION, CAUSALITY AND WAGNER'S LAW: EMPIRICAL EVIDENCE FROM CHINESE PROVINCES

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ABSTRACT

This paper tests Wagner's law of increasing state activity using panels of Chinese provinces. The paper's main methodological contribution is in that we employ for the first time in the literature on Wagner's law a panel unit root, panel cointegration and Granger Causality testing approach. Overall, we find mixed evidence in support of Wagner's law for China's central and western provinces, but no support for Wagner's law for the full panel of provinces or for the panel of China's eastern provinces.

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I. INTRODUCTION

Wagner’s law of “increasing expansion of public and state activities” postulates that as real income increases, there is a long-run tendency for the share of public expenditure to increase relative to national income (Wagner, 1883). Since the translation of Wagner’s writings into English in the late 1950s, a large empirical literature testing various specifications of Wagner’s law has emerged. There are several large multi-country studies which have reached mixed results. Abizadeh and Gray (1985) tested Wagner’s law for the period 1963-1979 for 55 countries and found support for Wagner’s law in the richer countries, but not poorer countries. Chang (2002) tested Wagner’s law for three emerging industrialized countries and three industrialized countries and found support for Wagner’s law in five of the six countries. However, in a later study, Chang *et al.* (2004) tested Wagner’s law for three newly industrialized countries in Asia and nine industrialized countries and found only mixed support for the law. Ram (1986) tested Wagner’s law for 63 countries over the period 1950-1980 and found little support for the law. Wahab (2004) found at best limited support for Wagner’s law in a study of 30 OECD countries, while Kolluri *et al.* (2000) found support for Wagner’s law in a study of the G7 economies. Afxentiou and Serletis (1996) found no support for Wagner’s law in a multi-country study of six European countries using data from the twentieth century, but Thornton (1999) found support for Wagner’s law in a study of six European countries employing nineteenth century data. Ansari *et al.* (1997) found no support for Wagner’s law in a study of three African countries, while Iyare and Lorde (2004) found broad support for Wagner’s law in a study of nine Caribbean countries.

There are also a number of studies which test Wagner’s law for single countries. These include studies for developed countries such as Canada (see e.g. Ahsan *et al.* 1996; Biswal *et al.* 1999); Japan (Nomura, 1995); Sweden (Henrekson, 1993); the United States (see eg. Yousefi and Abizadeh, 1992; Islam, 2001) and the United Kingdom (Gyles, 1991; Oxley, 1994). There are also studies for emerging countries such as Greece (Courakis *et al.,* 1993; Hondroyiannis and Papapetrou, 1995; Chletsos and Kollias, 1997); Iraq (Asseery *et al.,* 1999); Pakistan (Khan, 1990); Mexico (see eg. Hayo, 1994; Lin, 1995); South Korea (Abizadeh and Yousefi, 1998); Taiwan (Sun, 1997) and Turkey (Halicioglu, 2003; Cavusoglu, 2005). While there are some exceptions, most country-specific studies find evidence in favour of Wagner’s law.

The objective of this study is to examine Wagner's law using panel data from a sample of Chinese provinces. As a large developing transitional economy, China is an interesting test of Wagner's law. As Tobin (2005, p.730) put it: "Despite official claims about the dismantling of the bureaucracy, the size of China's state bureaucracy has continued to grow" since the introduction of market reforms. Tobin (2005) noted that the reasons for China's burgeoning bureaucracy in the market reform period since the late 1970s are typically couched in political terms focusing on resistance to change and the entrenchment of bureaucrats. Consistent with the theoretical underpinnings of Wagner's law, Oxley (1994) noted that bureaucratic expansion can be seen in terms of bureaucracy theories of government such as that proposed by Niskanen (1971). The argument is that government expenditure may rise disproportionately with real income due to a principal/agent problem. Bureaucrats, acting as rational utility maximizers deriving power and prestige from their positions, may be able to expand their sphere of influence at the expense of allocative or *X*-efficiency.

Tobin (2005) pointed out that consistent with Wagner's law the role of the state in China has become more complex since the introduction of market reforms. Since China relaxed restrictions on rural-urban migration at the same time as the introduction of market reforms, conservative estimates put the number of migrants who have entered China's coastal cities somewhere between 100 and 120 million (Roberts, 2002). On the eve of market reforms in 1978 China's urban population was 172 million (17.9 per cent of the population). In 2001 China's urban population had increased to 480 million (37.6 per cent of the population)(SSB, 2002, Table 4.1). The resulting urbanization process has increased the costs to the state in China which are manifest in the provision of housing, policing, sanitation and transport services

Another contributing factor is that as real income has increased in China, people have become more accustomed to and expect both a higher level and an improved quality of state services to match rising standards associated with increased GDP in other areas of their lives (Tobin, 2005). To test Wagner's law, Tobin (2005) regressed the size of the state sector on GDP over the period 1978-2001 employing Chinese national data. Consistent with the predictions of Wagner's law, he found that an increase in GDP has a positive effect on the size of the state sector in China. The problem with Tobin's (2005) analysis, though, is that he employed ordinary least squares and did not pre-test the stationarity of the data. Thus, his findings may suffer from the well-known problem of spurious regression (Granger and Newbold, 1974).

A feature of the current study is the use of provincial level data. Few studies have used data at the sub-national level to test Wagner's law. One such study is Abizadeh and Yousefi (1988) who tested Wagner's law using data for 10 states of the United States over the period 1950 to 1984. As Abizadeh and Yousefi (1988) noted, there are advantages in using data on government expenditure at the provincial or state level to test Wagner's law. First, one of the assumptions of Wagner's law is the prevalence of peace and stability, given Wagner did not consider the effect of wars on government expenditure. The use of provincial data is consistent with the peace and stability assumption since provincial governments do not incur military expenditure. Second, Wagner's law is premised on an assumption of similar cultural and institutional arrangements. While this issue is not a problem for time series studies, Bird (1971) argued that given cultural and institutional differences across countries, cross-sectional multi-country studies do not necessarily prove or disprove Wagner's law. Using sub-national data provides the means to exploit the cross-sectional dimension, while still minimizing the effects of cultural and institutional differences. Third, changes in international economic conditions would affect a central government's overall expenditure. The use of provincial data, however, minimizes such influences on state expenditures, since provinces do not usually adopt counteracting fiscal or monetary policy measures to offset the effects of international economic conditions.

A fourth advantage of using Chinese provincial data is that in addition to testing Wagner's law for a full panel of provinces, the law can be tested for smaller panels corresponding to the eastern, central and western regions of China. The eastern provinces of China have relatively high real incomes and the provincial governments are richer compared with the less developed central and western regions of China. In recent inequality studies of China, much research has focused on the disparities in income distribution and differences in economic growth between different regions. In terms of real GDP per capita, consumption expenditure per capita and gross value of industrial and agricultural output of the Chinese provinces, most studies have found that disparities between the eastern and inland provinces have shown sharp increases (see e.g. Jian 1996; Kanbur and Zhang, 1999; Ying, 1999; Song *et al.*, 2000; Lee, 2000; Yang, 2002; Bao *et al.*, 2002). Over the course of the 1990s, the gap between provinces in the coastal area and those in inland China widened in relative terms to the national average. Between 1990 and 2000 national real

GDP per capita (in 1990 prices) increased from 1886 RMB to 4843 RMB. Over that decade real GDP per capita in the eastern provinces increased from 2681 RMB to 7417 RMB, while real GDP per capita in the central and western provinces increased from 1340 RMB to 3072 RMB (SSB, various). Wagner originally conceived his law as being applicable to countries, or regions within countries, in the early stages of development. While China as a whole is a developing country, using provincial data offers an interesting perspective because it provides a means to test Wagner's law for panels of provinces within the same country which are at different stages of economic development.

The main methodological contribution of this paper is the use of a panel unit root and panel cointegration approach which has not been used before in the literature on Wagner's law. As discussed by Henrekson (1993), the findings from time series studies of Wagner's law conducted prior to the 1990s may not be robust because they did not pre-test the stationarity properties of the data. Since the 1990s it has become standard in the literature testing Wagner's law with time series data to employ a unit root and cointegration methodology. These studies, however, typically test Wagner's law either for a single country or a sample of countries, treating each country in the sample as a separate entity and do not exploit the panel properties of the data.

II. EMPIRICAL SPECIFICATION AND DATA

Three proxies that have been used in the literature to measure Wagner's formulation of 'increasing state activity' are government expenditure, government expenditure per capita and government expenditure as a share of GDP (Peacock and Scott, 2000). Among other studies, Bird (1971), Courakis *et al.* (1993), Gandhi (1971), Oxley (1994) and Ram (1992) use government expenditure. Studies such as Michas (1975), Burney and Al-Mussallam (1999) and Chang *et al.* (2004) use government expenditure per capita. Following the approach in Mann (1980), we use both government expenditure and government expenditure per capita in alternative specifications. Specifically we formulate two different versions of Wagner's law.

Model 1 has the form:

$$\ln \mathrm{EXP}_{it} = \alpha_{0i} + \alpha_{1i} \ln \mathrm{GDP}_{it} + e_t$$

Model 2 has the form:

$$\ln \mathrm{PCEXP}_{it} = \alpha_{0i} + \alpha_{1i} \ln \mathrm{PCGDP}_{it} + e_t$$

Here, $\ln \mathrm{EXP}$ is the natural log of real government expenditure; $\ln \mathrm{PCEXP}$ is the natural log of real government expenditure per capita; $\ln \mathrm{GDP}$ is the natural log of real GDP; $\ln \mathrm{PCGDP}$ is the natural log of real GDP per capita and the subscripts i and t denote the Chinese province and time, respectively. Model 1 is often described as the Peacock-Wiseman (1961) version of Wagner's law. Other early studies to employ Model 1 include Musgrave (1969) and Goffman and Mahar (1971). Model 2 represents Gupta's (1967) version of Wagner's law and it has been used in studies such as Michas (1975), Mann (1980), Chang (2002) and Chang *et al*. (2004). If Wagner's law holds, the coefficient on real income will be positive and the elasticity of government expenditure with respect to real income will exceed unity. We use data from a panel of 24 Chinese provinces for the period 1952 to 2003 for which data is available on real GDP, real government expenditure, real GDP per capita and real government expenditure per capita. Data for 1952-1989 are from Hsueh *et al.* (1993) and data for 1990 to 2003 are from various editions of *China Statistical Yearbook.*

III. METHODOLOGY AND EMPIRICAL FINDINGS

Valid tests of models 1 and 2 require that the data be stationary (integrated of order zero) or if non-stationary (integrated of order one), cointegrated. Prior to the 1990s, as noted in the introduction, many studies of Wagner's law used inappropriate estimation techniques when confronted with non-stationary time series data. Beginning with Henrekson (1993), Oxley (1994) and Hondroyiannis and Papaetrou (1995), time series studies of Wagner's law have employed unit root and cointegration methodologies, although not in a panel data framework. The most common approach to testing Wagner's law in the literature has been to treat some measure of real income as the exogenous variable in explaining the growth in government expenditure (as in Models 1 and 2). This is how Wagner seemed to view the basis of the law. However, the Keynesian perspective postulates that it is possible that causation could run from government expenditure to GDP. Studies from a Keynesian viewpoint, such as Holmes and Hutton (1990, p. 87), have showed the existence of "rather strong evidence that income is a *prima facie* cause of government expenditures". If unambiguous support for Wagner's law is to be inferred, it is important that unidirectional causality running from GDP to government expenditure be established.

Thus, our econometric methodology proceeds in four stages. First, we implement the Fisher ADF panel unit root test proposed by Maddala and Wu (1999) to ascertain the order of integration of the variables. Second, conditional on finding that all variables are integrated of order one we test for panel cointegration using the approach suggested by Pedroni (1999). Third, conditional on finding cointegration we calculate panel fully modified ordinary least squares (FMOLS) estimates of the coefficients on real GDP (for Model 1) and real GDP per capita (for Model 2). Fourth, we test for Granger causality between real GDP and real government expenditure (Model 1) and between real GDP per capita and real government expenditure per capita (Model 2).

ADF Fisher Panel Unit Root Test

Maddala and Wu (1999) proposed a panel unit root test based on Fisher (1932). The ADF Fisher panel unit root test combines the p-values of the test statistic for a unit root in each cross-sectional unit. The Fisher test is non-parametric and is distributed as a chi-squared variable with two degrees of freedom. Using the additive property of the chi-squared variable, the following test statistic can be derived:

$$\lambda = -2\sum_{i=1}^{N} \log_e \pi_i$$

Here, π_i is the p-value of the test statistic in unit *i*. An advantage of this test is that it can be used regardless of whether the null is one of integration or stationarity. We report the results from the ADF Fisher panel unit root test in Table 1 for real GDP, real GDP per capita, real government expenditure and real government expenditure per capita both with and without a time trend. We conduct this exercise for the full panel of 24 provinces plus a smaller eastern panel (11 provinces), central panel (seven provinces) and western panel (six provinces).[1] For the log-levels of real GDP, real GDP per capita, real government expenditure and real government expenditure per capita we are unable to reject the joint unit root null hypothesis at the 10 per cent level. However, when we conduct the joint unit root test for the first difference of each of these four variables we are able to reject the null at the 1 per cent level. This result implies that real GDP, real GDP per capita, real government expenditure and real government expenditure per capita are integrated of order one.

Insert Table 1

Pedroni's (1999) Panel Cointegration Test

Once the existence of a panel unit root has been established, the issue arises whether there exists a long-run equilibrium relationship between the variables. Given that each variable is integrated of order one, we test for panel cointegration using Pedroni's (1999) test. Pedroni's (1999) test entails estimating the panel cointegration regression:

$$y_{i,t} = \alpha_i + \rho_i t + \beta_{1i} x_{1i,t} + \ldots + \beta_{Mi} x_{Mi,t} + \varepsilon_{i,t}$$

Here $t = 1,...,T;\quad i = 1,...,N;\quad m = 1,...,M$, where T refers to the number of observations over time, N refers to the number of individual provinces in the panel, and M refers to the number of regression variables. First, following estimation we store the residuals $\hat{\varepsilon}_{i,t}$. Second, we difference the original data series for each province and compute the residuals for the differenced regression $\Delta y_{i,t} = \sigma_{1i}\Delta x_{1i,t} + \sigma_{2i}\Delta x_{2i,t} + \ldots + \sigma_{Mi}\Delta x_{Mi,t} + \eta_{i,t}$. Third, we calculate $\hat{L}_{11i}^2$ as the long run variance of $\hat{\eta}_{i,t}$ using any kernel estimator. Fourth, using the residual $\varepsilon_{i,t}$ of the original cointegrating equation, we estimate the appropriate autoregressive model. For non-parametric statistics, we estimate $\hat{\varepsilon}_{i,t} = \hat{\psi}_i \hat{\varepsilon}_{i,t-1} + \hat{\kappa}_{i,t}$ and use the residuals to compute the long run variance of $\hat{\kappa}_{i,t}$, denoted as $\hat{\sigma}_i^2$. The term λ_i (see below) is computed as $\hat{\lambda}_i = 1/2\left(\hat{\sigma}_i^2 - \hat{s}_i^2\right)$, where s_i^2 is just the simple variance of $\hat{\kappa}_{i,t}$. For parametric statistics, we estimate $\hat{\varepsilon}_{i,t} = \hat{\psi}_i \hat{\varepsilon}_{i,t-1} + \sum_{k=1}^{K_i} \hat{\psi}_{i,k}\Delta\hat{\varepsilon}_{i,t-k} + \hat{\mu}_{i,t}^*$, and use the residuals to compute the variance of $\hat{\mu}_{i,t}^*$, denoted as $\hat{s}_i^{*2}$. Using each of these steps, we construct the following statistics and then apply the appropriate mean and variance adjustment terms as reported in Pedroni (1999, p. 666, Table 2).

Panel v-Statistic:

$$Z_v = T^2 N^{3/2}\left(\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{\varepsilon}_{i,t-1}^2\right)^{-1}$$

Panel ρ-statistic:

$$Z_\rho = T\sqrt{N}\left(\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{\varepsilon}_{i,t-1}^2\right)^{-1}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\left(\hat{\varepsilon}_{i,t-1}\Delta\hat{\varepsilon}_{i,t} - \hat{\lambda}_i\right)$$

Panel t-statistic (non parametric):

$$\overline{Z}_t = \left(\sigma^2_{N,T} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}^{-2}_{11i} \hat{\varepsilon}^2_{i,t-1} \right)^{-1/2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}^2_{11i} \left(\hat{\varepsilon}_{i,t-1} \Delta \hat{\varepsilon}_{i,t} - \hat{\lambda}_i \right)$$

Panel t-statistic (parametric):

$$\overline{\overline{Z}}_t = \left(\tilde{s}^{*2}_{N,T} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}^{-2}_{11i} \hat{\varepsilon}^{*2}_{i,t-1} \right)^{-1/2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}^2_{11i} \hat{\varepsilon}^{*}_{i,t-1} \Delta \hat{\varepsilon}^{*}_{i,t}$$

Group ρ-statistic:

$$\tilde{Z}_\rho = TN^{-1/2} \sum_{i=1}^{N} \left(\sum_{t=1}^{T} \hat{\varepsilon}^2_{i,t-1} \right)^{-1} \sum_{t=1}^{T} \left(\hat{\varepsilon}_{i,t-1} \Delta \hat{\varepsilon}_{i,t} - \hat{\lambda}_i \right)$$

Group t-statistic (non-parametric)

$$\tilde{Z}_t \equiv N^{-1/2} \sum_{i=1}^{N} \left(\hat{\sigma}^2_i \sum_{t=1}^{T} \varepsilon^2_{i,t-1} \right)^{-1/2} \sum_{t=1}^{T} \left(\hat{\varepsilon}^{*}_{i,t-1} \Delta \hat{\varepsilon}^{*}_{i,t} - \hat{\lambda}_i \right)$$

Group t-statistic (parametric)

$$\tilde{\tilde{Z}}_t \equiv N^{-1/2} \sum_{i=1}^{N} \left(\sum_{t=1}^{T} \hat{s}^{*2}_i \varepsilon^{*2}_{i,t-1} \right)^{-1/2} \sum_{t=1}^{T} \hat{\varepsilon}^{*}_{i,t-1} \Delta \hat{\varepsilon}^{*}_{i,t}$$

Here $\hat{\sigma}^2$ is the pooled long-run variance for the non-parametric model given as $1/N \sum_{i=1}^{N} \hat{L}^{-2}_{11i} \hat{\sigma}^2_i$; $\hat{\lambda}_i = 1/2 \left(\hat{\sigma}^2_i - \hat{S}^2_i \right)$. $\hat{L}_i$ is used to adjust for autocorrelation in the panel parametric model, $\hat{\sigma}^2_i$ and $\hat{S}^2_i$ are the long-run and contemporaneous variances for individual i and $\hat{S}^2$ obtained from the individual ADF-test of $\varepsilon_{it} = \eta_i \varepsilon_{it-1} + \mu_{it}$. S^{*2} is the individual contemporaneous variance from the parametric model; $\hat{\varepsilon}_{it}$ is the estimated residual from the parametric cointegration; $\hat{\varepsilon}^{*}_{it}$ is the estimated residual from the non-parametric model; $\hat{L}_{11,i}$ is the estimated long-run variance matrix for $\Delta \hat{\varepsilon}_{it}$ and L_i is the ith component of the lower-triangular Cholesky decomposition of matrix $\mathbf{\Omega}_i$ for $\Delta \hat{\varepsilon}_{it}$ where the lag length determined using the Newy-West method.

The results of Pedroni's (1999) panel cointegration test based on the seven test statistics above are reported in Tables 2 and 3. Table 2 consists of results based on Model 1 in which real government expenditure is regressed on real GDP for the full panel and smaller eastern, central and western panels. Table 3 consists of results based on Model 2 in which real government expenditure per capita is regressed on real GDP per capita for the full panel and smaller eastern, central and western panels. The results suggest that both Models 1 and 2 are cointegrated at the 1 per cent level.[2]

Insert Tables 2 and 3

FMOLS Panel Estimates

Because both models are cointegrated we calculate FMOLS panel estimates for real GDP (Model 1) and real GDP per capita (Model 2). Consider the following cointegrated system for a panel of $i = 1,2,...,N$ provinces over time $t = 1,2,...,M$:

$$Y_{it} = \alpha_{it} + \beta X_{it} + \varepsilon_{it};$$

$$X_{it} = X_{it-1} + \varepsilon_{it}.$$

$Z_{it} = (Y_{it}, X_{it})' \sim I(1)$ and $\varpi_{it} = (\varepsilon_{it}, \mu_{it})' \sim I(0)$ with long-run covariance matrix $\Omega_i = L_i L_i'$. L_i is the lower triangular decomposition of Ω_i which can be decomposed as $\Omega_i = \Omega_i^0 + \Gamma_i + \Gamma_i'$, where Ω_i^0 is the contemporaneous covariance and Γ_i is a weighted sum of autocovariances. The panel FMOLS estimator for the β is:

$$\beta_{NT}^* = N^{-1} \sum_{i=1}^{N} \left(\sum_{i=1}^{T} (X_{it} - \overline{X}_i)^2 \right)^{-1} \left(\sum_{i=1}^{T} (X_{it} - \overline{X}_i) Y_{it}^* - T\hat{\tau}_i \right)$$

where

$$Y_{it}^* = (Y_{it} - \overline{Y}_i) - \frac{\hat{L}_{21i}}{\hat{L}_{22i}} \Delta X_{it}, \qquad \hat{\tau}_i \equiv \hat{\Gamma}_{21i} + \hat{\Omega}_{21i}^0 - \frac{\hat{L}_{21i}}{\hat{L}_{22i}} \left(\hat{\Gamma}_{22i} + \hat{\Omega}_{22i}^0 \right)$$

The results for the panel FMOLS estimates are reported in Table 4. For Wagner's law to hold, the elasticity of government expenditure with respect to real income must exceed unity. While the coefficient on real income is positive, it is less than one with the exception of the western panel. The elasticity for real GDP for the full sample is 0.34 while the elasticity for real GDP per capita for the full sample is 0.37. This result implies that a 1 per cent increase in real income results in a 0.34-0.37 per cent increase in real government expenditure. For the eastern panel, the coefficient on real income in Model 1 is 0.34 while the coefficient on real income per capita in Model 2 is 0.49, implying that a 1 per cent increase in real income results in a 0.34-0.49 per cent increase in real government expenditure in the eastern provinces. We find that for the central and western provinces the effect of real income on real government expenditure is the largest. For the central panel a 1 per cent increase in real income results in a 0.97-0.98 per cent increase in real government expenditure, which is close to unity. In the western provinces the effect of a 1 per cent increase in real income on real government expenditure is estimated to be 1-1.01 per cent, which comes closest of all the FMOLS panel estimates to supporting Wagner's law.

Insert Table 4

Granger Causality

Engle and Granger (1987) show that if two nonstationary variables are cointegrated, a vector autoregression (VAR) in first differences will be misspecified. In this study, because real government expenditure (per capita) and real GDP (per capita) are cointegrated when testing for Granger causality, we specify a model with a dynamic error correction representation. This means that the traditional VAR model is augmented with a one period lagged error correction term, which is obtained from the cointegrated model. The Granger causality test based on Model 1 is of the form:

$$\Delta \ln \mathrm{EXP}_{it} = \pi_{1g} + \sum_{p} \pi_{11ip} \Delta \ln \mathrm{EXP}_{it-p} + \sum_{p} \pi_{12ip} \Delta \ln \mathrm{GDP}_{it-p} + \psi_{1i} \mathrm{ECT}_{t-1}$$

$$\Delta \ln \mathrm{GDP}_{it} = \pi_{2g} + \sum_{p} \pi_{21ip} \Delta \ln \mathrm{GDP}_{it-p} + \sum_{p} \pi_{22ip} \Delta \ln \mathrm{EXP}_{it-p} + \psi_{2i} \mathrm{ECT}_{t-1}$$

The Granger causality test for model 2 is of the form:

$$\Delta \ln \mathrm{PCEXP}_{it} = \pi_{1g} + \sum_{p} \pi_{11ip} \Delta \ln \mathrm{PCEXP}_{it-p} + \sum_{p} \pi_{12ip} \Delta \ln \mathrm{PCGDP}_{it-p} + \psi_{1i} \mathrm{ECT}_{t-1}$$

$$\Delta \ln \mathrm{PCGDP}_{it} = \pi_{2g} + \sum_{p} \pi_{21ip} \Delta \ln \mathrm{PCGDP}_{it-p} + \sum_{p} \pi_{22ip} \Delta \ln \mathrm{PCEXP}_{it-p} + \psi_{2i} \mathrm{ECT}_{t-1}$$

Here all variables are as previously defined, Δ denotes the first difference of the variable, and p denotes the lag length. The significance of the first differenced variables provides evidence on the direction of the short-run causation while the t-statistics on the one period error correction term denotes long-run causation.

Insert Table 5

The results for the Granger causality tests are reported in Table 5. For the full panel of Model 1, there is bidirectional Granger causality between real GDP and real government expenditure in the short run while in the long run, consistent with Wagner's law, Granger causality runs from real GDP to real government expenditure. For the full panel of model 2 there is bidirectional Granger causality between real GDP per capita and real government expenditure in both the long run and short run. For each of the eastern, central and western panels, there is bidirectional Granger causality between real GDP (per capita) and real government expenditure (per capita) in the short run in both models. The long-run results, though, for the smaller panels are generally consistent with Wagner's law with unidirectional causality running from real income (per capita) to real government expenditure (per capita). Specifically, in Model 1 for the eastern panel there is long-run bidirectional Granger causality between real GDP and real government expenditure, while for the central and western panels long-run Granger causality runs from real GDP to real government expenditure. In Model 2, for each of the three smaller panels, long-run Granger causality runs from real GDP per capita to real government expenditure per capita.

IV. CONCLUSION

This paper has tested Wagner's law for China's provinces. In addition to a full panel of provinces we also utilized smaller panels corresponding to China's eastern, central and western provinces. The analysis represents a methodological advance over previous studies testing Wagner's law because we use a panel unit root, panel cointegration and Granger causality testing approach. The findings are consistent with Wagner's basic premise that the law is more applicable to countries, or in our case provinces, in their earlier stages of development. For the less developed, lower income central and western panels there is mixed support for Wagner's law. While the elasticity of government expenditure with respect to real income is about one in both cases, there is long-run unidirectional Granger causality running from real GDP to real government expenditure. There is less support for Wagner's law for China as a whole or for the higher income eastern provinces. While an increase in real income has a positive effect on government expenditure, the coefficient on real income is less than one in both instances across the two models. There is also some evidence of bidirectional long-run Granger causality between real income and real government expenditure for the full panel (Model 2) and the eastern panel (Model 1) of provinces.

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Table 1: ADF Fisher panel unit root test results

	Full Sample		Eastern Provinces		Central Provinces		Western Provinces	
	No trend	**Trend**	**No trend**	**Trend**	**No trend**	**Trend**	**No trend**	**Trend**
$\ln \text{GDP}$	0.1189	3.8713	0.0483	1.5941	0.0430	1.2609	0.0274	1.0164
	(1.0000)	(1.0000)	(1.0000)	(1.0000)	(1.0000)	(0.9999)	(1.0000)	(1.0000)
$\Delta \ln \text{GDP}$	515.431***	495.611***	188.086***	202.565***	147.711***	125.940***	179.635***	167.106***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
$\ln \text{PCGDP}$	0.9872	34.4884	0.0258	1.2835	0.0156	0.8166	0.0071	0.6695
	(1.0000)	(1.0000)	(1.0000)	(1.0000)	(1.0000)	(1.0000)	(1.0000)	(1.0000)
$\Delta \ln \text{PCGDP}$	371.128***	317.20***	147.612***	207.507***	150.062***	134.611***	195.299***	175.537***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
$\ln \text{EXP}$	0.0485	2.7696	0.3710	7.8387	0.3324	15.4123	0.2562	7.8278
	(1.0000)	(1.0000)	(1.0000)	(1.0000)	(1.0000)	(1.0000)	(1.0000)	(1.0000)
$\Delta \ln \text{EXP}$	492.973***	517.651***	203.638***	160.904***	84.0208***	79.9417***	107.741***	89.5650***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
$\ln \text{PCEXP}$	0.7473	18.6494	0.3253	4.8761	0.2352	10.6132	0.1869	3.1602
	(1.0000)	(1.0000)	(1.0000)	(1.0000)	(1.0000)	(1.0000)	(1.0000)	(1.0000)
$\Delta \ln \text{PCEXP}$	428.959***	384.726***	241.287***	216.017***	82.9099***	79.6250***	104.762***	89.084***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Note: The eastern region includes Beijing, Fujian, Guangdong, Guangxi, Hebei, Jiangsu, Liaoning, Shandong, Shanghai, Tianjin and Zhejiang. The central region includes Anhui, Heilongjiang, Henan, Hubei, Hunan, Inner Mongolia and Jilin. The western region includes Gansu, Guizhou, Ningxia, Qinghai, Shaanxi and Yunnan. Probability values are in parenthesis. *** denotes statistical significance at the 1 per cent level.

Table 2: Pedroni's panel cointegration test results for model 1

Test statistics	Full Sample	Eastern	Central	Western
Panel v-statistics	9.0556***	7.4721***	4.8979***	4.3842***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Panel rho-statistics	-9.0728***	-7.2452***	-4.7831***	-4.6972***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Panel pp-statistics	-8.6402***	-5.9377***	-4.6010***	-4.5496***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Panel adf-statistics	-8.7974***	-7.0827***	-4.6286***	-4.2860***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Group rho-statistics	-6.5857***	-5.6102***	-3.3179***	-3.2295***
	(0.0001)	(0.0001)	(0.0009)	(0.0012)
Group pp-statistics	-8.7609***	-6.0257***	-4.6173***	-4.5553***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Group adf-statistics	-9.1717***	-7.7355***	-4.7028***	-4.5061***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)

Note: probability values in parenthesis. *** denotes statistical significance at the 1 per cent level.

Table 3: Pedroni's panel cointegration test results for model 2

Test statistics	Full Sample	Eastern	Central	Western
Panel v-statistics	9.9381***	7.0280***	5.2888***	-4.6719***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Panel rho-statistics	-10.8835***	-8.6805***	-5.1271***	-4.5684***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Panel pp-statistics	-9.5732***	-6.9939***	-4.8471***	-4.4723***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Panel adf-statistics	-8.7073***	-5.9538***	-4.8177***	-4.2110***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Group rho-statistics	-7.7374***	-6.2634***	-3.5363***	-3.1747***
	(0.0001)	(0.0001)	(0.0004)	(0.0015)
Group pp-statistics	-9.2816***	-6.4536***	-4.8500***	-4.5865***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Group adf-statistics	-9.5303***	-6.8930***	-4.8936***	-4.4418***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)

Note: Same as Table 2.

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Table 4: FMOLS results

	Full sample	Eastern	Central	Western
Model 1	0.34***	0.34***	0.97***	1.00***
	(7.56)	(8.57)	(68.49)	(52.16)
Model 2	0.37***	0.49***	0.98***	1.01***
	(15.53)	(7.79)	(58.15)	(44.07)

Note: t-statistics are given in parenthesis. *** denotes statistical significance at the 1 per cent level.

Table 5: Granger Causality results

	Model 1			Model 2		
Full Panel						
Source of causation$\rightarrow$	$\Delta \ln EXP$	$\Delta \ln GDP$	ECM_{t-1}	$\Delta \ln EXP$	$\Delta \ln GDP$	ECM_{t-1}
$\Delta \ln EXP$	-	48.5631***	-0.1277***	-	65.7277***	-0.1116***
		(0.0000)	[-8.7839]		(0.0000)	[-9.1741]
$\Delta \ln GDP$	31.9348***	-	0.0029	33.9175***	-	0.0167**
	(0.0000)		[0.4029]	(0.0000)		[2.2474]
Eastern Panel						
Source of causation$\rightarrow$	$\Delta \ln EXP$	$\Delta \ln GDP$	ECM_{t-1}	$\Delta \ln EXP$	$\Delta \ln GDP$	ECM_{t-1}
$\Delta \ln EXP$	-	16.9782***	-0.1856***	-	28.0521***	-0.1908***
		(0.0000)	[-7.7415]		(0.0000)	[-6.9788]
$\Delta \ln GDP$	9.3593***	-	0.0340***	33.2090***	-	0.0101
	(0.0000)		[1.9599]	(0.0000)		[0.8383]
Panel C: Central Panel						
Source of causation$\rightarrow$	$\Delta \ln EXP$	$\Delta \ln GDP$	ECM_{t-1}	$\Delta \ln EXP$	$\Delta \ln GDP$	ECM_{t-1}
$\Delta \ln EXP$	-	28.5616***	-0.2048***	-	24.5484***	-0.2101***
		(0.0000)	[-6.2632]		(0.0000)	[-6.5467]
$\Delta \ln GDP$	26.4354***	-	-0.0059	13.0916***	-	0.0007

	(0.0000)		[0.3222]	[0.0000]		[0.0338]
Panel D: Western Panel						
Source of causation $\rightarrow$	$\Delta \ln EXP$	$\Delta \ln GDP$	ECM_{t-1}	$\Delta \ln EXP$	$\Delta \ln GDP$	ECM_{t-1}
$\Delta \ln EXP$	-	18.0004***	-0.1918***	-	18.3207***	-0.1603***
		(0.0000)	[-5.9261]		[0.0000]	[-5.2439]
$\Delta \ln GDP$	11.9596***	-	0.0042	10.5464***	-	-0.0084
	(0.0000)		[0.2564]	[0.0000]		[-0.5579]

Note: Probability values are given in parenthesis while t-statistics are given in square brackets. ** (***) denote statistical significance at the 5 per cent and 1 per cent levels respectively.

NOTES

[1] The eastern region includes Beijing, Fujian, Guangdong, Guangxi, Hebei, Jiangsu, Liaoning, Shandong, Shanghai, Tianjin and Zhejiang. The central region includes Anhui, Heilongjiang, Henan, Hubei, Hunan, Inner Mongolia and Jilin. The western region includes Gansu, Guizhou, Ningxia, Qinghai, Shaanxi and Yunnan.

[2] The reported results do not include a time trend. We also performed the Pedroni (1999) panel cointegration test with a time trend and found that the variables in both models were cointegrated.